Interrelations of Vegetation, Soils and Range Conditions Induced by Grazing[1]

JAMES O. KLEMMEDSON
2501 Russell Street, Berkeley 5, California

Accurate range analysis is one of a range manager's key tasks. With the help of a few ecological principles, he must appraise the evidence and determine the range condition and trend of each site. With the aid of management principles he then adjusts his management accordingly.

Several techniques for determining range condition have been developed in recent years (Dyksterhuis, 1949; Humphrey, 1949; Parker, 1951; Pickford and Reid, 1942; Schwan and Costello, 1951). Review of these techniques shows that soils receive little attention except for site classification. This neglect may be due in part to a lack of knowledge of soil and site responses to grazing. Studies of such responses are badly needed to provide specific soil and site indicators which would be useful in judging range conditions and trends. This paper reports the results of such a study. Its purpose was to determine the changes in vegetational cover, soil stability and physical condition of the soil that occur with declining range condition in the high mountain park type.

Study Area

The study area is a portion of the White River National Forest near Hiner Spring in western Colorado. Investigations were confined to the high mountain park type, at 10,000 feet elevation. Subalpine grassland, dominated by Thurber's fescue (*Festuca thurberi*), characterizes the better range condition classes. Slopes ranged from 5 to 20 percent.

The soils over the entire study area are azonal with A-C profiles and are derived from basic igneous rocks of the andesite-basalt group. The soils are shallow to deep (18-48 inches), well drained and of loamy texture. Mechanical analysis gave the following average results for the study area as a whole; sand, 32.1 percent; silt, 45.7 percent; and clay, 22.2 percent. The original soil sample contained 30.4 percent gravel.

The approximate climatic condition of the study area, obtained from graphs prepared by Baker (1944), shows a total annual precipitation of 29 inches. Seasonal precipitation for the growing season amounts to approximately 11 inches, and more than half of the total precipitation is in the form of snow. Mean July and January temperatures are approximately 54° F. and 13° F., respectively.

Methods and Procedures

Data were collected on good, fair and poor condition ranges on a "high mountain slopes site."[2] Duplicate areas, A and B, which were comparable in exposure, slope and soils were sampled. Data concerning vegetational cover and indicators of soil movement were recorded on five transects in each sampling area using a modification of Parker's three-step method (Parker, 1951).

Indicators of erosion observed and incorporated into Parker's method included orientation of litter, soil deposition, soil washing and crusting, and pedestalling of bunchgrass. A scheme of classifying the pedestals into four stages as described by Retzer (1947) was followed. An abbreviated description of each stage follows:

Stage I—Plant crown on a level or near level with surface of soil.

Stage II—Plant crown above level of soil surface around part of its perimeter; breaking away tends to occur on the downhill side of clumps.

Stage III—Plants on a soil pedestal above the adjacent surface on all sides.

Stage IV—Grass on top of the pedestal dead or nearly so; pedestal disintegrating.

Six core samples of the surface two inches of soil were collected from each sampling area for laboratory analysis of soil texture, organic matter content, volume weight and pore size distribution. For the latter analysis, measurements of percentage of water by volume at various tensions were recorded and serve as the index to the distribution of large and small non-capillary pores. A procedure described by Tanner and Jackson (1949) was followed.

Two infiltration test runs were conducted along each transect of the sampling area using tin-can infiltrometers similar to those described by Evanko (1950).

Results

Vegetation

Plant density decreases with deterioration in range condition. In each study area, density decreased more, however, from fair to poor condition than from good to fair condition. On good condition range, average plant density for the two areas studied was 48.3 percent;

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[2]*The "high mountain slopes site" was delineated into range condition classes with the aid of a Range Condition and Site Guide developed for the White River Drainage of Western Colorado by the Soil Conservation Service. This guide is based largely on the classification of Dyksterhuis (1949) employing the scheme of "increasers," "decreasers" and "invaders."*

for fair and poor condition ranges it was 42.1 percent and 24.1 percent, respectively.

Range in good condition displayed a high total percentage of "desirable" plant species (Table 1). Thurber's fescue (*Festuca thurberi*), dominant in the aspect, made up 35.3 percent of plant cover on the two areas studied. Sedges (*Carex spp.*), nodding brome (*Bromus anomalus*), and sheep fescue (*Festuca ovina*) were other desirable species, which, with Thurber's fescue, made up 62.1 percent of the composition on good condition ranges. Undesirable species comprised 13.6 percent.

On fair condition ranges, desirable species made up only 35.2 percent of the total composition of which 13.2 percent was Thurber's fescue and 18.4 percent sedges. Undesirable species decreased to 9.5 percent. Intermediate species, however, increased with declining range condition from 22.7 percent in good condition range to 51.7 percent in fair condition range. Some of the important intermediate species were polyanthus brome (*Bromus polyanthus*), slender wheatgrass (*Agropyron trachycaulum*), Kentucky bluegrass (*Poa pratensis*), Letterman's needlegrass (*Stipa lettermani*), wild dandelion (*Agoseris sp.*), aspen peavine (*Lathyrus leucanthus*) and western yarrow (*Achillea lanulosa*).

Thurber's fescue completely disappeared from the vegetational cover of poor condition ranges. Idaho fescue (*Festuca idahoensis*) and sedge, the only desirable species recorded, were found only in very meager amounts. Undesirable species comprised more of the composition than in fair condition and made up 32.4 percent of the

Table 1. Vegetational composition on good, fair and poor condition range.

	Condition Class and Area								
	Good			Fair			Poor		
	A	B	Aver.	A	B	Aver.	A	B	Aver.
Desirable Species	%	%	%	%	%	%	%	%	%
Festuca thurberi	33.0	37.7	35.3	10.4	16.0	13.2	—	—	—
Festuca idahoensis	—	—	—	5.4	—	2.7	1.6	—	0.8
Festuca ovina	2.1	—	1.1	—	0.5	0.3	—	—	—
Bromus anomalus	3.4	2.8	3.1	1.4	—	0.7	—	—	—
Carex spp.	22.1	23.0	22.5	12.8	23.9	18.4	—	1.8	0.9
Total	60.6	63.5	62.1	30.0	40.4	35.2	1.6	1.8	1.7
Intermediate Species									
Agropyron trachycaulum	0.5	0.8	0.7	5.4	3.4	4.4	7.5	9.6	8.6
Bromus polyanthus	—	—	—	6.6	0.5	3.6	7.1	6.1	6.6
Poa pratensis	—	—	—	—	—	—	—	0.9	0.5
Stipa lettermani	0.8	7.9	4.4	16.0	13.7	14.9	6.7	18.0	12.4
Aquilegia caerulea	—	—	—	—	0.5	0.3	1.6	—	0.8
Pseudocymopterus sp.	2.8	0.4	1.6	0.5	1.4	1.0	2.4	—	1.2
Agoseris sp.	9.6	3.2	6.4	10.4	11.7	11.1	20.9	14.5	17.7
Lathyrus leucanthus	1.7	4.5	3.1	5.2	4.3	4.8	14.2	8.8	11.5
Achillea lanulosa	6.0	4.0	5.0	7.8	9.6	8.7	1.9	0.9	1.4
Erigeron speciosus var. macranthus	0.8	1.6	1.2	4.2	1.4	2.8	—	1.7	0.9
Delphinium sp.	—	—	—	—	—	—	—	0.9	0.5
Thalictrum sp.	0.8	—	0.4	0.5	0.2	0.4	1.9	—	1.0
Total	23.0	22.4	22.7	56.6	46.7	51.7	64.2	61.4	62.8
Undesirable Species									
Viola spp.	3.4	—	1.7	—	1.4	0.7	0.8	—	0.4
Aster spp.	—	0.8	0.4	1.9	0.5	1.2	—	—	—
Lupinus spp.	—	—	—	—	—	—	0.8	—	0.4
Helenium hoopesii	—	—	—	1.2	0.7	1.0	14.1	17.5	15.8
Potentilla gracilis ssp. *nuttalli*	0.9	4.5	2.7	1.4	5.0	3.2	1.2	4.4	2.8
Eriogonum sp.	10.0	3.2	6.6	1.4	—	0.7	—	—	—
Cirsium sp.	—	0.4	0.2	—	—	—	7.1	9.2	8.2
Viguiera multiflora	—	—	—	2.8	—	1.4	7.1	—	3.6
Fragaria ovalis	—	4.0	2.0	—	2.7	1.4	—	1.7	0.9
Gilia aggregata	—	—	—	—	—	—	—	0.9	0.5
Total	14.3	12.9	13.6	8.7	10.3	9.5	31.1	33.7	32.4
Others	2.1	1.2	1.6	4.7	2.6	3.7	3.1	3.1	3.1
Plant Density Index	47.0	49.6	48.3	42.4	41.8	42.1	25.4	22.8	24.1

Table 2. **Relationship of plant density index, bare soil, erosion pavement, organic matter, volume weight and infiltration with stage of range condition.**

Condition	Area	Bare Soil	Erosion* Pavement	Litter	Plant Density Index	Organic** Matter	Volume** Weight	Infiltration
		%	%	%	%	%		*Minutes/Inch of water*
Good	A	5.6	3.8	40.8	47.0	10.4	0.930	5.36
	B	7.2	1.8	39.8	49.6	9.3	1.009	10.37
	Aver.	6.4	2.8	40.3	48.3	9.9	0.970	7.82
Fair	A	12.8	12.4	28.6	42.4	7.3	1.165	8.14
	B	17.2	13.8	23.8	41.8	7.1	1.147	9.28
	Aver.	15.0	13.1	26.2	42.1	7.2	1.156	8.71
Poor	A	35.6	17.6	16.6	25.4	6.7	1.158	43.23
	B	34.8	24.0	15.6	22.8	5.5	1.238	16.93
	Aver.	35.2	20.8	16.1	24.1	6.1	1.198	30.08

*Accumulations of rock material smaller than ¾ inch in diameter.
**Sample from surface two inches of soil.

composition. Important undesirable species were orange sneezeweed (*Helenium hoopesii*), thistle (*Cirsium sp.*), showy goldeneye (*Viguiera multiflora*) and Nuttall's cinquefoil (*Potentilla gracilis,* ssp. *nuttalli*).

Indicators of Erosion

Soil erosion indicators were increasingly more noticeable with deterioration of the range from good to poor condition (Table 2). On good condition ranges, the occurrence of indicators showed that soil was fairly stable, while on fair and poor ranges, the soil was obviously eroding.

Transect data showed a steady increase in percentage of bare soil with declining range condition, from 6.4 percent in good condition to 35.2 percent in poor condition. Percentage litter decreased uniformly. The litter cover formed a rather heavy mat on good ranges, while on fair ranges litter was noticeably thinner, and on poor condition range it was very scant and almost inconspicuous. On good condition range where the high percentage of litter complemented the crownspread of live vegetation, the small amount of bare soil was well dispersed. On range in poor condition, the less extensive and generally scant litter cover obviously furnished little protection to the surface soil. This was shown by the accumulation of gravel, and washing of soil which indicated that runoff and erosion had been taking place.

The most readily observed indicators of soil instability were the presence of an erosion pavement and plant pedestals. The occurrence of these indicators unmistakably showed that with declining range condition there was increased erosion activity. Practically no erosion pavement was found on good condition ranges but poor condition range had 20.8 percent.

The relationship between the pedestalling stage of bunchgrasses and range condition found by Retzer (1947) was for the most part confirmed by this study (Table 3). The cyclic nature of the pedestal stages described by Retzer was rather apparent, however, very few stage IV pedestals were found. Over 90 percent of the pedestals on good condition range were stage I, with the remainder in stage II and III. With declining range condition, stage II and III pedestals were increasingly more abundant. Of the stage I pedestals on fair and poor condition range, relatively few were old plants. Young plants on stage I pedestals were in close association with stage II and III pedestals the original soil surface of which was obviously higher than the present surface of stage I pedestals, indicating at least a second cycle of pedestalling. The presence of an erosion pavement on the same level with stage I pedestals was an additional clue to the cyclic nature of pedestals and amount of soil removed.

Alluvial soil deposits were observed most frequently on fair condition range. This might be explained by the fact that on poor condition range, bunchgrasses or other plants of sufficient basal area to inhibit continued downward movement were absent or few in number. However, oriented litter occurred most frequently on poor condition range. Evidently, the single or few-stemmed species and

Table 3. **The relationship between pedestalling stages of bunchgrass and range condition.**

Range Condition	Area	Pedestal Stage I	II	III	IV
		%	%	%	%
Good	A	93.4	5.5	1.1	—
	B	96.0	3.2	0.8	—
	Aver.	94.7	4.4	1.0	—
Fair	A	53.3	41.3	5.4	—
	B	66.6	19.7	12.4	1.3
	Aver.	60.0	30.5	8.9	0.7
Poor	A	22.3	44.3	33.4	—
	B	21.0	62.8	11.2	5.0
	Aver.	21.7	53.6	22.3	2.3

small rocks common to poor condition range obstruct the continued movement of this larger, but lower density material (leaves, stems, small sticks) more effectively than soil material. Rock pedestals and soil washing were closely associated with erosion pavement and bare ground and indicated current soil loss. Crusting of the surface soil was observed frequently on areas of bare soil surface.

Physical Properties of the Soil

Pore Size Distribution

Soils from good condition ranges retained more water at all tensions applied and hence were higher in percentage of both large and small non-capillary pore space than soils from fair and poor condition ranges (Fig. 1). Relatively small differences were found between soils from fair and poor condition ranges. In general, soils from area A were higher in percentage water retained than those from area B. Soils from poor condition range in area B retained the least amount of water at all tension settings, except one.

Soil Organic Matter

Soils throughout the two areas studied were relatively high in organic matter content (Table 2). Organic matter in soils from good condition ranges was 9.9 percent whereas soils from fair and poor condition ranges had 7.2 percent and 6.1 percent, respectively. In all three condition classes soils from area B were lower in percentage organic matter content than for area A. This was especially noticeable on good and poor condition ranges.

Volume Weight

The volume weight analysis showed increasingly higher values for soils from good to fair and poor range condition. As with pore size distribution and organic matter content, differences were greater between good and fair condition ranges than between fair and poor condition (Table 2).

Infiltration

Results from the infiltration trials were variable within all range conditions sampled. Data showed only slight differences in the rate of infiltration of one inch of water on good and fair condition ranges, 7.82 and 8.71 minutes, respectively. Poor condition range displayed low rates of infiltration, an average of 20.08 minutes, and considerable variation between A and B.

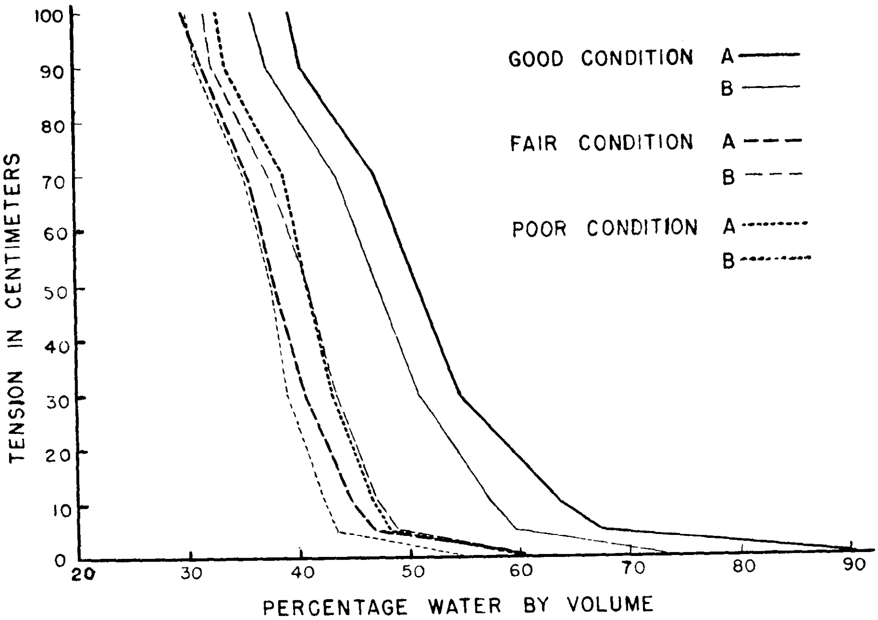

FIGURE 1. Percentage water by volume retained in the surface two inches of soil at various tensions on good, fair and poor condition ranges.

Discussion

The relationship between vegetational cover and range condition in the high mountain park type follows a pattern closely resembling that described by others (Dyksterhuis, 1949; Humphrey, 1945; Costello and Schwan, 1946) working in different types. The importance of the various vegetational criteria as tools in range condition classification cannot be questioned.

This study showed that the physical phase of the range complex deteriorated markedly with declining range condition. Changes in both the stability and the physical condition of the surface soil were distinctly evident. Many of these changes may be recognized, measured and used as criteria in judging range condition as well as vegetational criteria.

The erosion pavements observed indicated that erosion was or had been taking place. Although the amount of soil lost was not determined quantitatively, the pavements were indicative of the relative amount of erosion for the range condition classes.

Presence of pedestalled bunchgrass was one of the most apparent indicators of soil loss in this study. Pickford and Reid (1942) reported a similar relation on subalpine ranges in the Northwest. The relationship between distribution of pedestalling stages and range condition indicates that pedestalling of plants might be easily incorporated as a quantitative indicator for judging range condition.

Such indicators as deposits of alluvial soil material, orientation of litter, rock pedestals, and crusting and washing of soil surface are associated with an unstable soil mantle and are readily obliterated by natural causes. Therefore, they seem especially important in furnishing information on current happenings, and hence should be valuable as indicators in determining trend of range condition. The occurrence of all indicators of soil stability studied may be readily observed or measured quantitatively by many range sampling techniques.

Studies of volume weight, percentage organic matter, pore size distribution, and infiltration rate indicated that the physical condition of the soil had definitely deteriorated with decline in range condition. With the exception of infiltration, measurement of these soil properties ordinarily requires laboratory analysis. However, relative soil physical condition can be estimated indirectly by observing other indicators which give clues to absorptive rate of the soil, runoff and amount of erosion.

Degeneration was accompanied by progressive deterioration in both the physical and vegetational phase of the range complex. Greater change in the physical phase was noted in the earlier stages of range deterioration, from good to fair condition. Greatest change in the vegetational phase was noted in the later stages of range deterioration, from fair to poor. Ellison (1949) has described similar differential rates of change of vegetation and soil in range trend.

Differences were found in the two areas studied. Measurements of erosion pavement, volume weight and organic matter content showed deterioration of soil in Area B to be more advanced than that in Area A, although the vegetation was similar. The more depleted soil condition on Area B associated with vegetation closely similar to that on A under poor range condition may be explained on the basis that the vegetation of both areas, upon reaching a poor condition stage, had assumed a general equilibrium with the soil. However, with continued overuse for a longer period of time, the soil conditions on Area B had continued to deteriorate. The existence of different rates of trend for vegetational and soil conditions indicates that a two-fold condition analysis is probably needed.

It seems apparent from this study that indicators of soil stability and physical condition can be used as criteria in guides for determining range condition. An attempt should be made to include study of the physical phase of the range complex in range analysis which has been largely a vegetational analysis in the past.

Summary

1. Studies were made in the high mountain park type of western Colorado to determine the changes in vegetational cover, soil stability, and physical condition of the soil that occur with declining range condition.

2. After delineation into sites and range condition classes, the areas were sampled for plant density, composition and indicators of soil stability by a modification of Parker's 3-step method and by observation. Infiltration rates were measured with a tin-can infiltrometer. Data on the physical condition of the surface soil were obtained by laboratory analysis.

3. Plant density decreased with a downward trend in range condition. Desirable species diminished and intermediate and undesirable species showed an increase with deterioration in range condition. A greater change was noted from fair to poor than from good to fair condition.

4. Physical soil conditions also deteriorated with a downward trend in range condition. Prominent indicators of soil disturbance and instability such as erosion pavements, plant pedestalling, bare soil and degree of litter cover became more evident as the range deteriorated. Less noticeable indicators such as alluvial deposits, orientation of litter, rock pedestals, and soil washing and crusting furnish supporting evidence of trends and reveal current happenings.

5. As shown by infiltration studies and measurements of organic matter content, volume weight and pore-size distribution, the physical condition of the soil deteriorates with a trend from good to poor range condition.

6. The "state of health" of the physical phase of the range complex may be determined by practical methods and for management purposes. Indicators of soil disturbance show the relative degree of soil stability and may be readily observed and evaluated by range sampling techniques. The physical condition of the soil may be accurately determined only by laboratory analysis.

7. Soil indicators can be used as criteria in judging range condition and should be more fully used in what has largely been a vegetational analysis.

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